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USDA Forest Service
General Technical Report INT-67
INTERMOUNTAIN FOREST AND
RANGE EXPERIMENT STATION
FOREST SERVICE,
U.S. Department of Agriculture

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RESEARCH SUMMARY

The loss of a valuable salmonid fish population in the Panther Creek drainage of east-central Idaho led to studies designed to identify the source of toxic materials in the drainage. Numerous studies summarized here indicate that water seepage from adits of the no longer operating Blackbird Mine and leaching from mine waste piles are the principal sources of cobalt, copper, iron, manganese, lead, and zinc in the drainage. Downstream from the mined area, pH values have been lowered to levels lethal to aquatic organisms. High sediment loads in area streams are probably the result of stream scouring below the mined area. Sampling of the drainage yielded no fish nor aquatic insects in areas affected by mining. Upstream from mined areas, diverse populations of both fish and insects existed. Tests showed that trout fingerlings placed downstream from the mined area were killed. Elimination of fish populations from waters altered by mining in the Panther Creek drainage is probably the result of the long-term, chronic effects of heavy metal toxicity. Pollution from the mine, waste dumps, and tailings ponds will remain in the drainage until these areas are rehabilitated.

The research reported here was funded by the SEAM program. An acronym for Surface Environment and Mining, SEAM is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while helping to meet the Nation's mineral requirements. The SEAM program is a partnership with land managers, regional planners, mining industries, and political jurisdictions at all levels.

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INTRODUCTION

Acid water discharging from mines into streams is a pollution problem that has destroyed many fish populations throughout the country. The problem first gained prominence in the Eastern United States where large coal mines are operated in acid soils. A similar problem exists in the Western United States, where hard-rock mining exposes sulfide minerals to oxidation and results in the discharge of strong acids and heavy metals detrimental to aquatic life.

Such is the case with the Blackbird Mine on the Salmon National Forest near Salmon, Idaho. Sulfide ores were processed at the mine to isolate copper, cobalt, silver, and gold, and acid mine water resulted. Observations before 1967 seemed to indicate that operations of the Blackbird Mine caused the loss of anadromous and resident fish in the Panther Creek drainage. Later studies (Platts 1967, 1972) disclosed that a valuable resident sport fishery had been depressed and that runs of anadromous fish had been eliminated from the Panther Creek drainage.

From 1967 to 1972, the Forest Service conducted studies in the Panther Creek drainage to identify toxic elements present in the area and their effects on aquatic organisms. From 1972 to the present, additional information was collected by personnel from the Salmon National Forest, the Idaho Department of Health and Welfare, the University of Idaho College of Mines, and the Idaho Department of Fish and Game as part of a continuing program monitoring the Panther Creek drainage.

This report summarizes data from the above sources. Because of the variety of data sources and sample sites, this discussion deals only with trends in the variables, and will serve as a general summary of the pollution situation in the Panther Creek drainage.

The data analysis will provide the land manager with information important to planning. Future studies incorporating this data would allow land managers to evaluate the effectiveness of rehabilitation projects and management decisions, as well as the long-term effects of acid mine water drainage on fish populations.

STUDY AREA DESCRIPTION

The Blackbird Mining District is 25 mi (40 km) southwest of Salmon, Idaho. Blackbird, Meadow, Bucktail, and Big Deer Creeks drain the mined area and flow into Panther Creek. Panther Creek enters the Salmon River about 51 mi (82 km) below Salmon, Idaho. The Panther Creek watershed is approximately 600 mi^2 (1,550 km^2) and ranges in elevation from 3,300 to 10,000 ft (1,000 to 3,040 m). The drainage is characterized by steep mountain slopes and canyons with steep gradients.

The Panther Creek headwaters are in the Belt Series, a geologic formation of Precambrian quartzite and argillite with some intermixtures of calcareous rock and basalt. Downstream from the headwaters, Panther Creek is in the Idaho Batholith, which is composed mainly of decomposing granitic rocks.

The mean discharge of Panther Creek is 248 ft^3/s (421.6 m^3/min). High water runoff begins about April 1 and continues through June (Andreesen 1972). During high flows, flooding often occurs and the potential for stream scour is high. As a consequence, sediments from tailing dumps and waste piles in the mined area are transported downstream and often are redeposited on the flood plains and in channels of lower Blackbird Creek and Panther Creek (Figure 1).

Figure 1.--Sediment in Blackbird Creek below the mill (March 1967).

Blackbird Creek enters Panther Creek 35 mi (57 km) above the mouth of Panther Creek. The elevation of Blackbird Creek ranges from 5,100 to 8,200 ft (1,560 to 2,500 m). Blackbird Creek is over 9 mi (15 km) in length and drains 23 mi^2 (60 km^2) with a mean discharge of 10.0 ft^3/s (70.2 m^3/min). Flow at the mouth varies from a low of 3.5 ft^3/s (5.9 m^3/min) in January to a high of 40.6 ft^3/s (68.9 m^3/min) in June (Andreesen 1972). Farmer (personal communication) has estimated high flows at up to 70 ft^3/s (118 m^3/min).

Mining History

Mining activity in the Blackbird Mining district began in 1893 and has been sporadic since that time. Mining properties have gone through numerous ownerships and are currently controlled by the Idaho Mining Company. All production operations were stopped in 1967. While it was operated, the mine produced copper, gold, and cobalt ores. The Idaho Mining Company as full lease holder recently has been engaged in exploring the property. Future plans call for reopening some underground workings and two new open pit operations in the area.

Water from the mine, waste piles, and portals drains directly into Meadow Creek, a tributary of Blackbird Creek. The Blacktail open pit is located at the headwaters of Bucktail Creek. Bucktail Creek also receives runoff from numerous mine portals and waste piles. This creek is a tributary of Big Deer Creek, which flows into Panther Creek.

The mill is located near the confluence of Blackbird and Meadow Creeks. A coffer dam was built on Blackbird Creek in the 1940's to contain and divert mining wastes. A piping system that parallels Blackbird Creek carries and dumps the waste into a tailings pond on the West Fork of Blackbird Creek. Settling ponds were also constructed on Blackbird Creek immediately upstream from the mouth of the West Fork. During milling operations, frequent leaks and breaks occurred in the conduit system which combined with the water overflow and breaks in the coffer dam. Because the collection facility was ineffective, large amounts of mine waste continued to enter the Blackbird and Panther Creek system (Figures 2 and 3).

Figure 2.--High water heavily laden with mine tailings bypassing the coffer dam on Blackbird Creek (May 1967).

Figure 3.--Acid water seepage from the Blackbird Mine shaft (August 1970).

Since the mine closed in 1967, some restoration work has been done in the drainage. Personnel from the Salmon National Forest did channelization work on Blackbird Creek. In addition, the Intermountain Forest and Range Experiment Station has planted experimental vegetation plots on disturbed mining sites in the Blackbird Creek drainage (Farmer, Richardson, and Brown 1976). Despite these efforts, the mine, waste dumps, and tailings pond continue to pollute Blackbird and Panther Creeks. Waterflow from mine adits and seepage from the tailings pond still heavily pollute the drainage. Spring runoff will continue to scour the waste dumps and stream channels and deposit sediment downstream until the dumps are stabilized (Figure 4).

Figure 4.--The confluence of Blackbird and Panther Creeks showing the high turbidity of Blackbird Creek (September 1969).

History of Fishery

Panther Creek historically served as a spawning and nursery area for chinook salmon [*Onocorhynchus tshawytscha* (Walbaum)] and steelhead trout [*Salmo gairdneri* (Richardson)] and as residential waters for trout and mountain whitefish [*Prosopium williamsoni* (Girard)]. Local residents reported that chinook salmon and steelhead trout were numerous in Panther Creek before 1945 (Corley 1967). Idaho Department of Fish and Game records show that a large fish kill occurred in Panther Creek during March, April, and July, of 1954. Among the dead fish were 200 adult chinook salmon, steelhead and resident trout, and whitefish. Fish and Game redd counts in 1954 confirm use of Panther Creek by chinook salmon. In 1957, the number of salmon redds counted came to 135; in 1962, only 13 adult chinook salmon spawned near the mouth of Porphyry Creek, a tributary of Panther Creek above Blackbird Creek (Pence 1966). Electrofishing by Corley (1967) identified rainbow trout [*Salmo gairdneri* (Richardson)], eastern brook trout [*Salvelinus fontinalis* (Mitchell)], mountain whitefish, sculpin (*Cottus* sp.), longnose dace [*Rhinichthys cataractae* (Valenciennes)], and suckers (*Catostomus* sp.) in the drainage. Pence (1966) added Dolly Varden [*Salvelinus malma* (Walbaum)] and cutthroat trout [*Salmo clarki* (Richardson)] to this list.

Aquatic Insects

Panther Creek was used by diverse families of insects for oviposition, nymph development, and larval metamorphosis. Panther Creek bottom samples contained populations of four insect orders, all commonly used as food by salmon and trout (Corley 1967). They were: (1) midges (Diptera); (2) caddisflies (Trichoptera); (3) mayflies (Ephemeroptera); and (4) stoneflies (Plecoptera).

METHODS

Water Chemistry Sampling

Sampling procedures followed those outlined in Standard Methods for the Examination of Water and Waste water (1971). Intermountain Forest and Range Experiment Station personnel sampled 23 stations in the Panther Creek drainage from 1967 through 1970. From 1974 through 1976, researchers from the University of Idaho College of Mines sampled 27 stations in the area. Stations sampled were:

Forest Service stations	Location
1B	Blackbird Creek--above mill
2B	Blackbird Creek--below mill
3B	West Fork Blackbird Creek--above tailings pile
4B	West Fork Blackbird Creek--below tailings pile
5B	Blackbird Creek--mouth of Blackbird Creek
8B	Slippery Creek--above confluence, Blackbird Creek
9B	Ludwig Creek--above confluence, Backbird Creek
10B	Blackbird Creek--Mine discharge water--6,850 portal
11B	Meadow Creek--immediately above mill
12B	Meadow Creek--between St. Joe portal and Blackbird Creek
13B	Meadow Creek--1-1/2 miles upstream from mouth
14B	Meadow Creek--above mining activity
1P	Panther Creek--below confluence, Moyer Creek
2P	Copper Creek--above confluence, Panther Creek
3P	Panther Creek--above confluence, Napias Creek
4P	Panther Creek--above confluence, Little Deer Creek
5P	Little Deer Creek--above confluence, Panther Creek
6P	Big Deer Creek--above confluence, Panther Creek
7P	Panther Creek--Rams Point Campground
8P	Panther Creek--above confluence, Salmon River
9P	Salmon River--above confluence, Panther Creek
10P	Panther Creek--above confluence, Blackbird Creek
11P	Panther Creek--below confluence, Blackbird Creek

University of Idaho stations	Location
1	Blackbird Creek--below mouth of West Fork
2	West Fork Blackbird Creek--below tailings pile
3	West Fork Blackbird Creek--above tailings pile
4	Blackbird Creek--above mouth of West Fork
5	Slippery Creek--mouth of Slippery Creek
6	Blackbird Creek--below mill
7	Blackbird Creek--mine discharge water, 6,850 portal
8	Blackbird Creek--above mill
9	Meadow Creek--below St. Joe portal
10	Meadow Creek--below 7,100 waste pile
11	Meadow Creek--below mouth of Spring Creek
12	Spring Creek--mouth of Spring Creek
13	Meadow Creek--1-1/2 miles upstream from mouth
14	Meadow Creek--2 miles upstream from mouth
15	Meadow Creek--7,400 portal
16	Meadow Creek--above mined area
17	Meadow Creek--below Forest Service waste pile
19	Bucktail Creek--below Blacktail Pit
20	Bucktail Creek--7,265 portal
21	Bucktail Creek--below 7,265 portal
22	Bucktail Creek--7,117 portal
23	Bucktail Creek--1-1/2 miles upstream from mouth
24	Bucktail Creek--mouth of Bucktail Creek
25	South Fork Big Deer Creek--above mouth of Bucktail Creek
26	South Fork Big Deer Creek--below mouth of Bucktail Creek
27	South Fork Big Deer Creek--mouth of South Fork Big Deer Creek
28	Big Deer Creek--below mouth of South Fork of Big Deer Creek

This report also presents data from recent collections at seven sites on Meadow and Blackbird Creek made by personnel from the Salmon National Forest. Although some of the sites were duplicated in the sampling program, a total of 47 different sites were sampled (fig. 5).

Water samples were collected in polyethylene bottles that had been rinsed with acid and cleansed with hot distilled water. For the 1967-1970 study, two samples were collected at each station, a 4-oz (115-ml) sample for heavy metal analysis and a 16-oz (450-ml) sample for the remainder of the tests. For the heavy metal analyses, the 4-oz (115-ml) bottle was acidified with 0.04 oz (1 ml) of nitric acid. Samples were either delivered immediately to the laboratory or were frozen for later analysis. Water was analyzed for total solids, total dissolved solids, copper, iron, cobalt, silver, arsenic, boron, cadmium, calcium, chlorine, chromium, fluorine, mercury, potassium, magnesium, manganese, sodium, nitrate, lead, sulfate, zinc, nickel, phosphate, hardness, and alkalinity. Analyses were conducted according to procedures outlined in Standard Methods for the Examination of Water and Wastewater (1971). Water samples were analyzed by chemists at the Idaho State Department of Health and Welfare Laboratory in Boise, Idaho, and the Environmental Protection Agency, Pacific Northwest Water Laboratory, Corvallis, Oregon. Samples collected by University of Idaho personnel were not acidified. These were analyzed at laboratory facilities provided by the Idaho Mining Company at Cobalt, Idaho. A Hach portable chemical analysis kit was used in the field to analyze dissolved oxygen and pH. An Imhoff cone was used in the field to analyze suspended sediment.

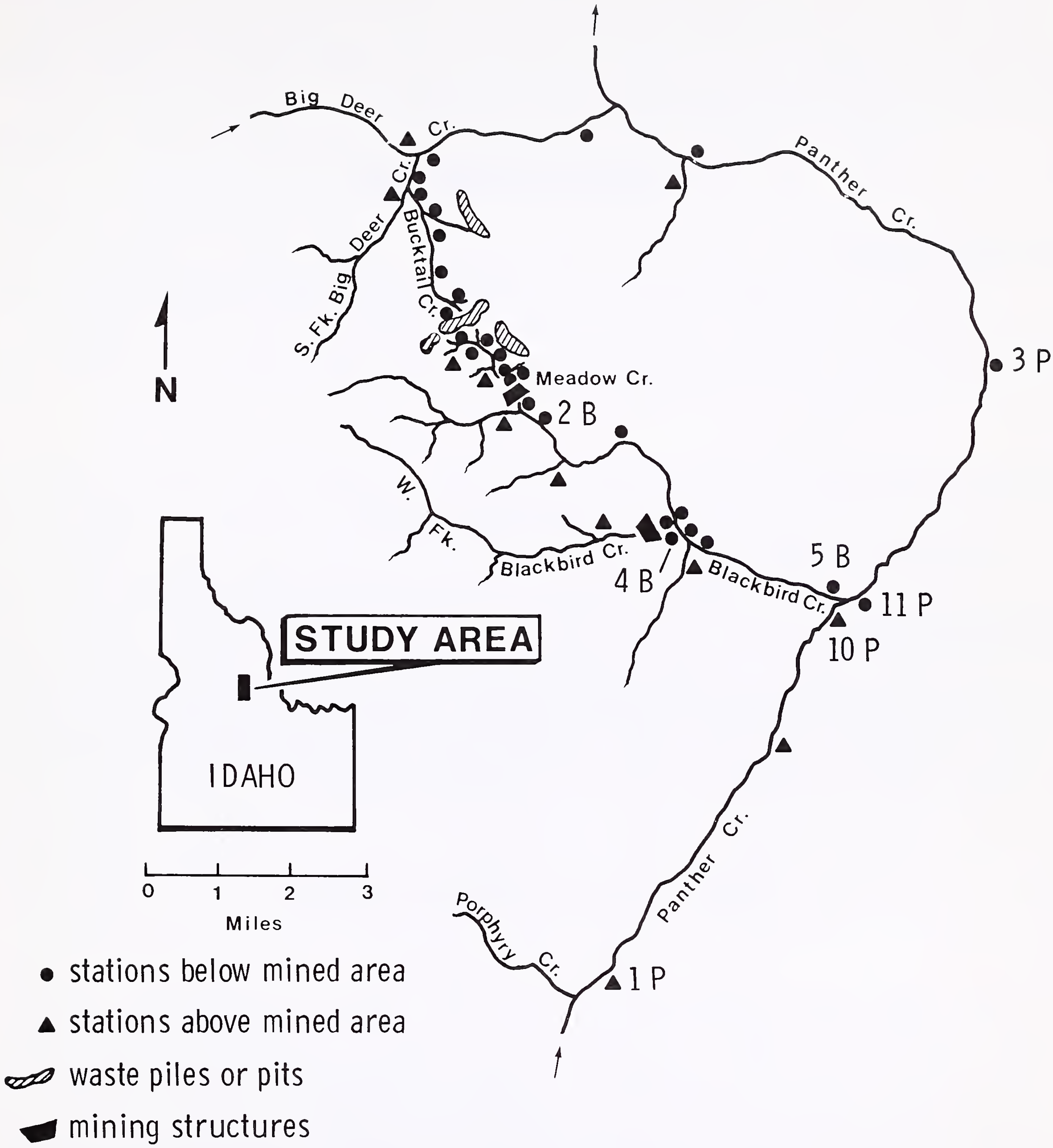

Figure 5.--Sample sites in the Panther Creek drainage.

Channel substrate samples were taken with a 6-in (152-mm) diameter core sampler designed by McNeil (1964). Core samples were analyzed in the Forest Service Materials Laboratory, Intermountain Region, Salt Lake City, Utah, by heat drying and straining the materials through sieves. The amount of fine sediment (mainly clays) passing through the smallest sieve size was determined by hydrometric analysis. Other sediment size class amounts were determined by direct weighting.

Biological Sampling

AQUATIC INSECTS

In 1967, Corley sampled aquatic insect populations at four Panther Creek stations. At each station, five 2-ft^2 (0.19-m^2) benthic samples were taken. A circular frame covered with window screen (14 mesh per inch [6 mesh per cm]) was used to collect insects dislodged from the stream bottom. The insects were placed in glass vials and preserved for analysis of number and order.

FISH POPULATION

Fish populations were sampled with an electrofisher at five Panther Creek stations and one Blackbird Creek station in 1967.

FINGERLING TROUT

One hundred rainbow trout fingerlings, averaging 3 inches (7.7 cm) in length, were placed in one of two "live" boxes (Corley 1967). The boxes were 1.5 by 2 by 3 ft (46 by 61 by 91 cm) in dimension, and were covered by a 1/4-inch (0.64-cm) mesh hardware cloth. The boxes were placed in at least 1 ft (30 cm) of water at three Panther Creek stations. After 3 days, the fish were checked for survival.

RESULTS AND DISCUSSION

Water Chemistry

For easy discussion of water quality in the Blackbird Mining District, data in this report are presented as being collected upstream or downstream from the mined area. Sites upstream from the mining district receive no pollutants from the mined area, while those downstream are subject to input from the mine and its portals, open pits, waste piles, tailings ponds, and any water seepage from these sources. Selected results from the water chemistry testing are given in Table 1. These data are for the most extensively tested variables and readily reflect any mining-related pollution in the drainage. Tables 2 and 3 present a summary of the data by sample site. Although mean concentrations of heavy metals appear to decrease at the sample sites farthest downstream from the mined area, concentrations generally remain higher than natural background levels.

Table 1.--*Mean concentrations of selected water chemistry variables in the Blackbird mining area, 1966 to 1977. Sample size in parenthesis*

Sample sites	Variable											
	pH range	Alkalinity	Hardness	Cobalt	Copper	Iron	Lead	Manganese	Zinc	Suspended solids	Dissolved solids	Total solids
		-mg/liter-										
Upstream from mined area	3.4-8.5 (29)	52.2 (7)	87.1 (19)	0.29 (11)	0.26 (31)	0.6 (45)	0.04 (12)	0.6 (20)	0.03 (14)	12.4 (18)	182 (16)	140 (19)
Downstream from mined area	2.7-8.5 (74)	34.8 (33)	100 (28)	26.3 (59)	76.3 (100)	19.2 (100)	0.03 (29)	6.5 (70)	0.07 (31)	52.9 (22)	185.6 (25)	275.4 (29)

Note: mg/liter are equivalent to parts per million (ppm)

Table 2.--*Summary of selected data from Forest Service sample stations in the Panther Creek drainage, 1966 to 1977*

Station	Variable						
	pH range	Cobalt	Copper	Iron	Lead	Manganese	Zinc
		mg/liter					
1B	7.0	--	0.05	0.1	--	--	--
2B	3.2-3.4	--	5.8	11.8	<0.01	1.3	0.007
3B	--	--	.01	.09	<.01	.01	<.001
4B	5.3-6.9	--	.2	.7	<.01	.26	.006
5B	5.3-6.9	--	1.3	8.9	<.01	.76	.06
8B	--	--	.01	.15	--	--	--
9B	--	--	.03	.12	--	--	--
10B	2.7	--	13.5	71.5	.06	14.1	.2
11B	--	--	16.7	21.8	<.01	3.4	.1
13B	--	--	11.5	5.2	--	--	--
14B	--	--	.2	.1	--	--	--
1P	7.3-8.3	0.009	.009	.2	--	.01	.02
2P	8.0-8.3	.006	.01	.1	<.01	.006	.01
3P	8.4	--	.4	1.4	.01	.09	.02
4P	8.5	--	.08	.8	.01	.05	.02
5P	--	.04	--	.05	.07	.02	.04
6P	8.4	.18	.17	.2	.01	.02	.01
7P	8.4	.26	.009	.7	.01	.04	.02
8P	7.5-8.4	.18	.08	.5	.01	.04	.01
9P	7.4-8.5	--	.03	.7	<.005	.04	.01
10P	8.0-8.4	.005	.009	.2	.01	3.3	.01
11P	6.5-8.2	.4	.09	1.0	.01	.07	.1

Note: mg/l are equivalent to parts per million (ppm)

Table 3.--*Summary of selected data from University of Idaho sample stations in the Panther Creek drainage, 1974 to 1976*

Station	Variable				
	pH range	Cobalt	Copper	Iron	Manganese
		- - - - - - - - - - -*mg/liter*-			- - - - - - - - - -
1	3.7-4.9	1.6	2.4	0.8	0.9
2	2.9-7.3	1.4	.05	5.0	4.0
3	4.0-7.5	.3	.1	.6	.1
4	3.0-4.7	2.4	3.0	2.9	.9
5	3.8-6.0	.7	.1	.3	.3
6	3.1-5.1	3.8	8.8	4.9	2.7
7	2.2-4.2	22.8	54.6	245.0	7.9
8	4.4-7.5	.6	.1	.7	.5
9	2.7-3.6	20.2	14.2	28.0	3.8
10	2.4-4.1	21.7	44.9	27.4	3.7
11	2.9-3.4	9.5	21.2	4.6	1.9
12	3.4-7.3	.3	1.8	2.9	.3
13	3.0-3.3	13.5	24.9	5.0	2.9
14	3.4-5.2	6.7	15.6	.9	.8
15	2.6-3.0	42.3	151.9	78.2	11.8
16	4.6-7.0	.5	.3	.3	.3
17	3.5-4.3	59.1	290.0	.7	11.0
19	3.5-4.6	208.0	1384.9	17.5	29.7
20	2.6-12.0	82.7	111.9	99.6	22.9
21	2.8-4.2	136.0	850.9	44.4	36.7
22	2.8-3.2	24.6	17.8	21.9	9.9
23	3.1-4.4	54.0	270.0	7.6	9.1
24	4.3-5.3	11.3	33.1	.3	1.4
25	5.3-7.8	.03	.03	.2	.3
26	5.4-7.2	1.3	2.5	.1	.3
27	5.5-7.4	.1	.0	.2	.3
28	3.9-6.9	.4	.4	.1	.1

Note: mg/l are equivalent to parts per million (ppm)

The results of statistical F-tests made on the data showed that significant differences (P = 0.05) occurred between sample mean values upstream and downstream from the mined area. Mean values for cobalt, copper, iron, manganese, zinc, and suspended and total solids were found to be significantly greater below the mining district than above it. Differences in levels of alkalinity, hardness, lead, and dissolved solids were not statistically significant.[1] A complete collection of the data summarized in this study is on file at the Intermountain Station's Research Laboratory in Boise, Idaho.

COBALT

Trace amounts of cobalt ions appear to stimulate growth of some organisms (McKee and Wolf 1971). Cobalt concentrations of up to 1.0 mg/liter were not harmful to 1-year-old tench, carp, rainbow trout, and char, nor to the crustaceans, worms and insect larvae that are the food of these fish (Schweiger 1961); however, at higher concentrations, cobalt ions have been toxic. The mean concentration (26.3 mg/liter) of cobalt below the mining influence in the Panther Creek drainage was well above 10 mg/liter, a concentration lethal to sticklebacks (Jones 1939).

[1]The sampling schedule for all other variables was sporadic; so any analysis would be difficult.

COPPER

Copper has been well documented as an aquatic pollutant. The U.S. Public Health Service allows 1.0 mg/liter copper in domestic drinking water, a limit that was set primarily because of the bad taste that develops above this level (U.S. Public Health Service 1962). The California State Water Control Board has recommended an allowable maximum concentration of 0.02 mg/liter of copper in waters inhabited by fish and other aquatic life (McKee and Wolf 1971). This allowable level is exceeded in the Panther Creek drainage even in the waters above the mined area (0.26 mg/liter copper), but this may reflect some sampling or analytical errors. High levels of copper may be tolerated by aquatic organisms for a short period, provided they are not subjected to stress from other factors. Downstream from the mined area, the mean copper concentration was about 300 times greater (76.3 mg/liter) than that found upstream (0.26 mg/liter). This concentration virtually guarantees that no aquatic organism will survive in this area (Wilson 1972). A more detailed discussion of effects of copper on the aquatic biota appears in the section on biological components.

IRON

According to Ellis (1940), 95 percent of the waters in the United States that support good fish populations have iron concentrations of 0.7 mg/liter or less. Iron concentrations higher than 1 to 2 mg/liters are indicators of acid pollution (Ellis and others 1946). Mean concentrations of iron in stream sections above the Panther Creek mining district were suitable for survival of aquatic life (0.6 mg/liter).

The toxicity of iron appears to result from the action of specific iron salts or from the precipitate that forms from the combination of iron and hydroxyl ions. Fish apparently are killed by coatings of iron oxide or hydroxide precipitates on the gills (van Duijn 1967). In addition, Sykora and others (1972) found a definite trend toward smaller juvenile brook trout when fish were exposed to ferric hydroxide for a long period. They suggested that the precipitate impaired visibility, which caused feeding difficulties and resulted in slower growth. In well-aearated waters, ferrous ions may oxidize to ferric ions, which readily form insoluble hydroxides. If the pH and oxidation-reduction potential of the waters do not favor such compounds, high concentrations of iron ions may remain in solution (Hem and Cropper 1959). The mean iron concentrations (19.2 mg/liter) in the Panther Creek drainage below the mined area were definitely toxic.

MANGANESE

Manganese is essential to both plant and animal nutrition. To insure good taste, limits in drinking water have been set at 0.05 mg/liter (McKee and Wolf 1971). Jones (1939) gave 40 mg/liter as the lethal concentration of manganese for the stickleback (*Gasterosteus* sp.). Permanganates, which are unstable in water, are lethal to fish at lower levels ranging from 2.2 to 4.1 mg/liter (Iwao 1960). Manganese at levels found in the Panther Creek drainage might not poison aquatic organisms, but may contribute to synergistic toxicity reactions. This situation arises when two or more heavy metals at tolerable levels act in concert to produce a toxic reaction in organisms. Synergism is a common problem with heavy metals.

LEAD

The toxicity of lead alone probably is slight in the study area. The mean levels of 0.04 to 0.03 mg/liter lead upstream and downstream from the mined area are well below the documented toxicity levels. For example, rainbow trout in soft water were

killed at lead concentrations of 1.0 mg/liter (Brown 1968). Carpenter (1927) found fish were killed in lead concentrations of 0.3 mg/liter, a concentration at least 10 times greater than the mean concentrations in the drainage. However, lead is another element that may react with other metals to produce a combined toxicity greater than their individual concentrations.

ZINC

Mean zinc concentrations in the study area apparently were below levels toxic to aquatic organisms. Fish mortalitites usually do not occur at zinc concentrations below 0.3 mg/liter, even in soft waters that have a hardness of 10 mg/liter or less (Sprague 1964a). Since the waters in the Panther Creek drainage range from 87.1 to 100 mg/liter hardness, some protection against zinc toxicity can be expected: however, zinc concentrations in waters downstream from the mining district could be a problem because of zinc's synergistic activity with copper, a metal already present in toxic quantities.

pH

Water samples from sites downstream from the mined area had consistently lower pH values than those upstream (table 1). Generally, a favorable pH range for fish is from 6.5 to 8.7 (U.S. Environmental Protection Agency 1976). Levels below that range can be tolerated without biological damage for short periods, provided the level is attributable to natural organic acids (McKee and Wolf 1971). In streams influenced by mining, a low pH usually indicates the presence of inorganic sulfuric acid, which is involved in the oxidation of ferrous sulfate to ferric sulfate, a soluble toxic form of iron. Ferric sulfate also reacts to free inactive copper in chalcopyrite to form toxic copper sulfate. Both compounds are highly toxic to aquatic organisms.

SEDIMENT

Sediment sampling from 1966 to 1968 showed that a large quantity of fine sediment in Blackbird and Panther Creeks was seriously degrading water quality and channel substrate. Much of the sediment was directly attributed to past operations at Blackbird Mill. Over the 2-year period, selected water samples were taken from five stations downstream from the mined area in the Panther Creek drainage. Samples contained from 400 to 60,900 mg/liter suspended solids. Samples taken for the same study from a station upstream from the mining district showed 0 mg/liter suspended solids.

A particle size analysis of stream channel materials in Blackbird and Panther Creeks indicated that much of the fine sediment deposited during 1968 was from previous Blackbird mining and milling operations. Channel sediment particle size was drastically reduced below the input of the mine and waste piles. Average particle size of channel material collected from selected sites in the Panther Creek drainage was as follows:

Stations	Particle size
	mm
10P (Upstream from mined area)	22.4
11P (Downstream from mined area)	0.22
2B (")	5.78
4B (")	3.50

The large quantities of suspended solids downstream from the mined area would have caused high mortality among salmonid embryos and fry existing in these areas. Fine sediment in the quantities recorded reduces the permeability of spawning gravels and blocks the interchange of subsurface and surface water (Cooper 1959; Koski 1966; McNeil 1964; Vaux 1962).

The mean concentration of total solids at sites downstream from mined areas was significantly higher (275.4 mg/liter) than it was upstream from the mining district (140 mg/liter) (table 1). Damage to the aquatic environment from increased turbidity is direct; photosynthesis is reduced because of light reduction and high amounts of suspended solids interfere with efficient respiration of gilled animals (Coker 1968). Young salmoids are particularly susceptible to gill irritation caused by turbid water, which then exposes them to infection by fungi and bacteria (Bell 1973).

Biological Sampling

AQUATIC INSECTS

Corley's (1967) insect sampling clearly showed the effects the Blackbird Mine has had on aquatic organisms in the area (table 4). Station 1P, the station farthest upstream from the mined area had the greatest number of insects per unit area of streambed. Station 10P, also upstream from mine water input had slightly lower average numbers of insects than station P. Downstream from the confluence of Blackbird and Panther Creeks there were either no insects or a low number of insects (fig. 6). The insect that first reappeared in Panther Creek below the mouth of Blackbird Creek was the midge, which is tolerant of high copper concentrations (up to 2.2 mg/liter) (Surber 1959). Some caddisfly larvae may be equally tolerant of heavy metal pollution (Sprague and others 1965). Most mayfly nymphs cannot survive in streams with heavy metal concentrations far below concentrations lethal to trout (McKee and Wolf 1971). For example, Warnick and Bell (1969) found 0.3 mg/liter iron toxic to mayflies, stoneflies, and caddisflies. Fish populations, however, may tolerate iron concentrations up to 1.0 mg/liter (Ellis 1940). These figures indicate the highly sensitive nature of aquatic insects to heavy metal pollution.

Table 4.--*The mean number of aquatic insects in bottom samples collected from Panther Creek (Corley 1967)*

Insects	Stations: Upstream from mined area		Stations: Downstream from mined area	
	1P	10P	11P	3P
Midge (Diptera)	26.8	10.0	0	0.6
Caddisfly (Trichoptera)	15.1	3.6	0	.0
Mayfly (Ephemeroptera)	3.0	6.6	0	.0
Stonefly (Plecoptera)	2.0	3.8	0	.0
Bug (Hemiptera)	.5	.0	0	.0
Beetle (Coleoptera)	.0	.0	0	.4
Unidentified	.0	.0	0	.4
Total	47.4	24.0	0	1.4

Figure 6.--Stream channel rubble from Panther Creek below the confluence with Blackbird Creek showing a lack of aquatic insects and a heavy sediment coat (March 1966.)

In 1976 and 1977, Mangum (1978) sampled macroinvertebrates, water chemistry, and sediment concentrations at six stations in the Panther Creek drainage. Above the confluence of Blackbird and Panther Creeks, he found a healthy insect community typical of high mountain cold water streams in which sedimentation is moderately excessive. Insect diversity at the site was excellent and biomass was good. The insect community was dominated by clean water species (mayflies, stoneflies, and caddisflies). At five stations below the confluence, however, insect diversity was never rated better than poor. Biomass generally ranged from poor to fair, even at downstream sites far from the confluence. At sites below the confluence, insect communities were generally dominated by "drift through" organisms and by pollution-tolerant chironomids and dipterans. Apparently, downstream dilution of the discharge from the Blackbird mine is not great enough to allow recovery of aquatic macroinvertebrates in the drainage.

FISH POPULATIONS

From 1954 to 1967, the annual chinook salmon redd count conducted by the Idaho Department of Fish and Game indicated that spawning populations of chinook salmon had been eliminated from the Panther Creek drainage. From 1963 to 1967, no salmon redds were found, although from 1954 to 1962 an average of 51 redds per year were observed. Official counts were discontinued after 1967, but no redds were seen during field checks from 1968 to 1977.

Electrofishing yielded the highest numbers and variety of species of fish at station 1P, the site on Panther Creek most upstream from the mouth of Blackbird Creek (table 5). At station 10P, nearer the confluence of Blackbird and Panther Creeks, both numbers and species of fish were reduced. No fish were found at station 11P, immediately downstream from the confluence. Farther downstream at station 3P, a few fish, representing only two species were detected. Sampling at the mouth of Blackbird Creek (station 5B) indicated that no fish were present, as did spot checks in Blackbird Creek itself.

Table 5.--*Number of fish by species found at selected sample sites in the Panther Creek drainage (Corley 1967)*

Species	Station upstream from mined area		Station downstream from mined area		
	1P	10P	11P	3P	5B
Rainbow trout	26	20	0	8	0
Eastern brook trout	3	2	0	1	0
Whitefish	27	0	0	0	0
Sculpin	2	0	0	0	0
Dace	3	0	0	0	0
Unidentified	5	2	0	0	0
Total	66	24	0	9	0

Few if any fish in a stream can suggest fish avoidance of undesirable conditions rather than toxic concentrations of heavy metals. Absence of fish could also suggest a combination of avoidance and intoxication. Sprague (1964b) found that the lowest metal concentration causing a migrating salmon to show an avoidance response in soft water was 0.002 mg/liter copper (as copper sulfate) or 0.005 mg/liter zinc (as zinc sulfate). Avoidance by fish also occurred at a mixture of 0.0004 mg/liter copper and 0.006 mg/liter zinc. These concentrations are well below those found to be acutely toxic to fish and illustrate how sensitive salmonids are to heavy metal pollution. Fish would certainly avoid the copper and zinc concentrations found in the upper Panther Creek drainage.

FINGERLING TROUT SURVIVAL

In 1972 rainbow trout fingerlings confined in "live" boxes at sites on Panther Creek upstream and downstream from the confluence with Blackbird Creek, showed highly significant differences in survival. The line between excellent and poor fingerling survival was the point where Blackbird Creek enters Panther Creek. Fish placed in Panther Creek upstream (station 10P) from any input of acid mine water had only a 2 percent mortality rate, but the mortality rate of those fish below the confluence of Blackbird and Panther Creeks ranged from 86 percent at station 11P to 48 percent at station 3P, located farther downstream from the entrance of Blackbird Creek.

In 1975, Kent Ball[2] used live box tests to evaluate the effects of stream channelization work on Blackbird Creek by the Salmon National Forest. He found that channelization increased mortality of juvenile steelhead trout in Panther Creek. In a follow-up study in 1976, percent mortality was still higher than prechannalization rates.

Studies by the Idaho Bureau of Mines and Geology show an increase in the concentration of heavy metals in mine drainage water during high flows (Baldwin and others 1978). Such flows correspond to the time when juvenile salmon and steelhead trout would normally be migrating in the Panther Creek drainage. In April 1977, Ball set live boxes in Panther Creek in an atempt to assess fish mortality during the migration period. After 5 days, he found that fish mortality was 100 percent below Blackbird Creek and 20 percent below Big Deer Creek.

[2] Ball, Kent. 1978. Panther Creek fish status report. Idaho Dept. Fish and Game.

EFFECTS OF HEAVY METALS ON FISH

Dissolved heavy metals, commonly found in waters polluted by industrial mining operations, are toxic to the aquatic biota (Cairns and Scheier 1957; Lloyd 1960, 1961a, 1961b; Lloyd and Herbert 1962; Mount and Stephen 1967; Tarzwell and Henderson 1960). However, it is difficult to determine the actual metal concentration toxic to fish.

Toxicity depends on fish species, age, and stage of development (Lloyd 1960), water temperature (Chapman 1973), pH, dissolved oxygen concentration, and total hardness. In general, fish mortality results from exposure to high concentrations of a metal, and continuous low levels of a metal produce chronic effects, such as behavioral changes, reproductive failure, or fry mortality (Chapman 1973). Both ultimately affect the survival of a species in a stream.

Doudoroff and Katz (1953) reviewed nine research studies on the effects of heavy metal ions in water. They reported that the studies attributed death of fish in waters containing dissolved heavy metals to coagulation or precipitation of mucus secreted by the gills or to direct damage to gill tissue. Skidmore and Tovell (1972) found that the specific toxic action of zinc was to the epithelial tissue of the gills.

The virtual disappearance of fish in the Panther Creek drainage is probably the result of acute toxicity as well as of long-term effects of chronic heavy metal toxicity. Drummond and others (1973) found behavioral changes in brook trout at concentrations as low as 0.005 mg/liter copper. Studies on brook trout by McKim and Benoit (1971) showed that copper concentrations of 0.002 to 0.03 mg/liter had no effect on adult fish, but a marked effect on survival and growth of alevins and juveniles. Zinc concentrations of 0.18 mg/liter were found by Brungs (1969) to greatly reduce egg production of the fathead minnow (*Pimephales promelas* Rafinesque), a fish more resistant to heavy metal toxicity than the salmonids. In the same study, Brungs found that fathead minnow growth was inhibited and mortalities occurred at 2.8 mg/liter zinc. Holcombe and others (1976) found that long-term exposure of brook trout to lead resulted in physiological changes. In three generations of fish exposed to lead concentrations ranging from 0.001 to 0.5 mg/liter, second and third generation trout developed spinal deformities (scoliosis). In additon, growth of third generation trout was reduced.

High concentrations of heavy metals in a stream result in very toxic conditions, in behavioral changes, in avoidance, and in long-term chronic toxicity to fish. Any or all of these factors could be responsible for the reduction or elimination of fish populations from the Panther Creek drainage.

CONCLUSIONS

Results of studies discussed here suggest that past mining activities in the Blackbird mining district have caused extensive pollution of the Panther Creek drainage. Sediment and dissolved heavy metals from mining and milling operations have virtually eliminated the aquatic biota, including anadromous salmon and steelhead trout in affected areas.

Heavy metals present in toxic concentrations are cobalt, copper, iron, manganese, zinc, and possibly lead. Not only are these elements toxic at the concentrations found, but synergistic toxic reactions can occur. The mine waters also contribute mineral acidity that decreases the pH in drainage streams, another factor detrimental to aquatic life. In addition, lowered pH levels result in increased solubilities of heavy metals in the water.

Heavy sediment loads and deposition downstream result from the erosion of waste dumps, tailings piles, and stream scouring during periods of high runoff. Such pollution will continue in the affected areas until extensive reclamation is done in the mine area.

These data can be used as baseline information to evaluate the effects of future mining or reclamation activity. The information presented here should alert the land manager to potential pollution problems that can result from mining activities. In addition, data reported demonstrate the need to rehabilitate areas disturbed by mining.

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Discusses studies made from 1967 through 1977 that show seepage from the no longer operating Blackbird Mine in east central Idaho has resulted in acidic waters high in sediment and heavy metals. Suggests high concentrations of cobalt, copper, iron, manganese, lead, and zinc in the Panther Creek drainage are the probable cause of diminished insect and fish populations in the area. Contends that pollution from the mined area will remain a problem in the drainage until rehabilitative measures are taken.

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